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Developmental Science, 23(6)

DOI or URL to published work (if available) 10.1111/desc.12974

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The Intergenerational Transmission of Mathematics Achievement in Middle Childhood: A Prospective Adoption Design

Research Highlights

- Birth parent mathematics achievement was positively related to adopted child mathematics achievement at age 7, indicating heritable influences on mathematics outcomes.
- Adopted child mathematics achievement was positively related to adoptive father, but not mother, mathematics achievement, indicating differential parent influences on mathematics outcomes.
- Findings indicated no significant gene-by-environment interactions on children’s mathematics achievement in middle childhood.
- Results suggest the unique contributions of heritable *and* environmental influences on children’s mathematics achievement in middle childhood.

Abstract

The present study uses a parent-offspring adoption design to examine the dual roles of heritable and environmental influences on children's mathematics achievement. Linked sets (*N* = 195) of adopted children, adoptive parents, and birth parents each completed a measure of mathematics fluency (i.e., simple computational operations). Birth parent mathematics achievement and adoptive father mathematics achievement positively correlated with child achievement scores at age 7, whereas adoptive mother and adopted child mathematics achievement scores were not significantly associated with one another. Additionally, findings demonstrated no significant effects of gene-environment (GxE) interactions on child mathematics achievement at age 7. These results indicate that both heritable and rearing environmental factors contribute to children' mathematics achievement and identify unique influences of the paternal rearing environment on mathematics achievement in middle childhood.

Keywords: mathematics achievement; heritability; fathers; intergenerational transmission; GxE interplay; middle childhood

The Intergenerational Transmission of Mathematics Achievement in Middle Childhood: A Prospective Adoption Design

Low mathematics achievement is prevalent in the United States. For example, on the 2017 National Assessment of Educational Progress (2017), only 40% of U.S. fourth graders were at or above proficiency on measures of mathematics achievement. Because early mathematics achievement establishes critical trajectories for future academic achievement (Jordan et al., 2009; Watts et al., 2014), young children who struggle to grasp basic mathematics concepts early in schooling are at risk for facing similar challenges later in schooling. Investigations into the etiologies of mathematics achievement can elucidate the factors that contribute to mathematics achievement across childhood. The present study used an adoption design to estimate heritable (i.e., from birth parent mathematics achievement) and environmental (i.e., from adoptive mother and father mathematics achievement) contributions to variability in mathematics achievement in middle childhood.

The Intergenerational Transmission of Mathematics Achievement

Intergenerational transmission is a process by which parents intentionally or unintentionally transfer psychological and behavioral traits to their offspring (Hart et al., 2019; van Bergen et al., 2014). A limited, but growing literature examines the transfer of mathematics knowledge from parents to offspring, with findings demonstrating positive associations between parent and child mathematics achievement (Braham & Libertus, 2017; Blevins-Knabe et al., 2007; Brown et al., 2011; Duncan et al., 2009; Heineck & Riphahn, 2009; Hertz et al., 2007; Navarro et al., 2018; Plug & Vijverberg, 2003; Sacerdote, 2002). Illustratively, a recent study found that, even after controlling for other factors, parent mathematics achievement positively predicted 5- to 8-year old children's mathematics achievement (Braham & Libertus, 2017).

A common interpretation of positive parent-child associations in the behavioral psychology literature is that they reflect environmental transmission processes (e.g., socialization, modeling) that underlie parental investments in offspring via time, resources, and parental behaviors. These environmental processes are thought to causally explain links between parent variables (e.g., achievement, behaviors) and child mathematics achievement. In line with this notion, recent work has begun to study effects of family environment factors, including socioeconomic status (SES; Elliott & Bachman, 2018), domain-specific parental language (mathematics and spatial language; Borriello & Liben, 2018; Gunderson & Levine, 2011), and the home numeracy environment (Huntsinger et al., 2016; LeFevre et al., 2009; Melhuish et al., 2008) on child mathematics achievement. Although study findings are inconsistent, they sometimes demonstrate positive correlations between these factors and child mathematics achievement (e.g., Blevins-Knabe et al., 2000; Missall et al., 2015; Thompson et al., 2017).

Intervention research provides additional support for the notion that child mathematics achievement is influenced by environmental factors. For example, early education intervention programs have been shown to enhance later academic achievement (Campbell et al., 2012), and some programs specifically target parents. One preschool program increased children's school readiness gains beyond initial effects of a classroom intervention by supplementing classroom exposure with a parent-targeted home-learning curriculum (Bierman et al., 2017). Thus, most correlational and experimental work examining links between parent factors and child mathematics achievement suggests parents can be a source of *environmental variability* for children's mathematical learning, and that what parents *do* with children influences individual differences in mathematics achievement.

A Behavioral Genetics Approach to Individual Differences in Mathematics Achievement

An issue with assuming that socialization factors (e.g., parental input, other experiential factors) explain parent-child associations is that most developmental studies examine parent-child associations using biologically related parents and children. The use of biologically related families makes it challenging to discern whether parent-child associations are due to influences of shared genes between parents and children (i.e., heritable influences), to influences of the experiences parents and children share, or to some combination thereof (Moore & Neiderhiser, 2014; Plomin et al., 1977).

Genetically sensitive designs have the power to clarify the contributions of environmental processes (i.e., parental socialization) on the intergenerational transmission of developmental outcomes by studying families with varying degrees of genetic relatedness (e.g., twin and sibling studies, adoption studies). Twin and sibling studies can account for both similarity (shared environment) and differences (nonshared environment) in the environment shared by family members to estimate effects of heritable and environmental influences. Such studies indicate large effects of heritable influences and small, but significant, effects of shared environmental influences on mathematics achievement in middle childhood (Hart et al., 2010; Hart et al., 2009; Kovas et al., 2013; Kovas et al., 2007; Luo et al., 1994; Petrill et al., 2012; Thompson et al., 1991). Adoption studies can estimate heritable and rearing environmental contributions to parent-offspring similarity by examining family triads (i.e., birth parents, adoptive parents, and the adopted child). Specifically, birth parents provide genes to the adopted child placed in adoptive homes at or near birth (and birth mothers provide the prenatal environment) but do not provide the rearing environment, whereas genetically unrelated adoptive parents provide the child's rearing environment. Few adoption studies examine the etiology of mathematics achievement, however, studies investigating IQ, a related construct (Alarcón et al., 2000),

indicate slightly larger effects of heritable compared to environmental influences (Scarr & Weinberg, 1977; Loehlin et al., 1989). Genetically informed research thus suggests that both heritable *and* environmental factors are key contributors to the intergenerational transmission of mathematics achievement.

Gene-environment Interplay

Behavioral genetics research can clarify the unique contributions of heritable and environmental factors on human traits and behaviors. Although these estimates are important, far more complex processes, which involve the interplay between heritable and environmental factors, including gene-environment correlation (*r*GE) and gene-environment interaction (GxE), also drive child development (Moore & Neiderhiser, 2014; Plomin et al., 1977). GxE is a process by which effects of an environment (e.g., home learning environment) depend on individuals' genetic propensities. Behavioral genetics designs are uniquely suited to unpack these processes and reveal exactly *how* complex behavioral traits develop over time.

Prior GxE work has examined whether family environmental factors, including SES, moderate heritable influences on children's cognitive abilities and academic achievement (Tucker-Drob et al., 2011; Rhemtulla & Tucker-Drob, 2012; Turkheimer et al., 2003). For example, Rhemtulla and Tucker-Drob (2012) found that heritable influences on mathematics achievement at age 4 were larger for children raised in higher, rather than lower, SES families. These findings suggest that heritable contributions to mathematics achievement depend on the quality of family environmental factors children experience.

This study uses a parent-offspring adoption design to examine GxE interactions. The adoption design can examine GxE interactions because the birth parent and adoptive parents provide unique contributions to child outcomes, with birth parents providing heritable influences,

as the child is placed with adoptive parents closely after birth, and adoptive parents providing the postnatal environment for the adopted child. This has the added benefit of eliminating any potential confounds of passive *r*GE (when design assumptions are met; i.e., no selective placement) and helping to better specify potential GxE findings.

The Present Study

To disentangle heritable and environmental pathways of intergenerational transmission, we examined whether birth parents' mathematics achievement (heritable influences) and adoptive parents' mathematics achievement (rearing environmental influences) were associated with the adopted child's mathematics achievement at age seven. We also examined whether contributions of heritable influences on children's mathematics achievement were moderated by the quality of the rearing environment (i.e., levels of adoptive parent mathematics achievement).

A secondary study question concerned effects of biological sex of the adoptive parents and the adopted child on children's mathematics achievement at age 7. Very little work has examined whether parent biological sex differentially influences children's mathematics achievement. Some behavioral work suggests that parent biological sex influences children's learning experiences, such that mothers engage in more achievement-related activities, including homework, with their children than do fathers (Grolnick & Slowiaczek, 1994; Levin et al., 1997). Foster et al. (2016) found that, even though engagement in educational activities at home with young children was higher for mothers than fathers, both maternal and paternal educational involvement predicted children's mathematics achievement. However, this finding was only true for children whose mothers had earned less than a bachelor's degree. For children with more highly educated mothers, only maternal, and not paternal, educational involvement predicted children's mathematics achievement. Another study found that mothers', compared to fathers',

engagement in mathematics-related activities at home was more related to children's mathematics performance in early schooling (del Río et al., 2017). These studies also align with the finding that mothers are children's primary caregivers (Craig, 2006; Nomaguchi et al., , 2005). To the best of our knowledge, this study is the first genetically informed study to examine whether pathways between parent and child mathematics achievement vary by parent biological sex.

Investigations into the influence of child biological sex on mathematics achievement have been of long-standing interest to psychologists. Early research demonstrated a gender gap in mathematics achievement, favoring boys over girls (e.g., Anastasi, 1958; Benbow & Stanley, 1980). Since the 1990s, however, meta-analyses and other studies examining this question have found mounting evidence mathematics achievement does not differ between males and females (Hyde et al., 1990; Hyde, 2005; Hyde et al., 2008; Kersey et al., 2018; Lindberg et al., 2010). Almost no behavioral genetics work has examined effects of child biological sex on mathematics achievement. Kovas, Haworth, Petrill, & Plomin (2007) found no differences in the etiologies of boys' and girls' mathematics achievement at age 10. The present study uses an adoption design to examine whether the etiologies of boys' and girls' mathematics achievement differ at age 7.

Hypotheses

We hypothesized that (1) birth parent mathematics achievement (heritable influences) would be positively associated with adopted child mathematics achievement, that (2) there would be differential effects of adoptive parent mathematics achievement (rearing environmental influences) on child mathematics achievement, such that adoptive mothers' influence would explain a unique amount of variance above and beyond variance explained by adoptive fathers' achievement, although both associations would be positive, and that (3) adoptive mother, but not

adoptive father, mathematics achievement would moderate the effects of birth parent mathematics achievement (GxE interaction) on child mathematics achievement such that heritable influences would be stronger when adoptive mothers had higher, rather than lower, mathematics achievement. For child biological sex, we did not expect to find differential etiologies of boys' and girls' mathematics achievement. Finally, we had no expectations for whether adopted child sex would differentially impact effects of heritable, environmental, or GxE interactions, as no behavioral genetics study has previously considered differential effects of both parent and child biological sex on the etiology of mathematics achievement.

Method

Participants and Procedure

Participants were from Cohort I of the Early Growth and Development Study (EGDS; *N* = 195 adoption-linked families, each consisting of an adopted child, adoptive parents, and a birth mother and birth father), a multisite, longitudinal study of adopted children and their birth and adoptive parents (Leve et al., 2019). Birth fathers participated in 34.9% of the families. At the time of assessment, adopted children were 7 years old (M_{age} = 7.01 years; *SD* = .15; Range = 6.76 to 7.49 years). Table 1 displays additional descriptive information about the analytic sample. Participants were recruited from 2003 to 2006 from adoption agencies throughout the United States. Families were eligible for the study based on the following criteria: (a) the adoption was domestic, (b) the child was placed prior to 3 months of age (*M* = 7.11 days postpartum, *SD* = 13.28), (c) the child was placed with a non-relative adoptive family, (d) the infant had no known major medical conditions (e.g., extreme prematurity; extensive medical surgeries), and (e) the birth and adoptive parents could at least read or understand English at an eighth-grade level. Data collection occurred via home visit assessments and online

questionnaires. For additional information about study recruitment procedures, sample, and assessment methods, see Leve et al. (2019).

Attrition Analysis

One hundred and sixty six of the 361 participating families were excluded from analyses because of listwise deletion (listwise $n = 195$). One hundred and forty participating families were excluded from analyses because at least one member of every family unit (birth mother, adoptive mother, adoptive father, adopted child) was missing data from main study variables, and another 21 families were missing data from a relevant covariate. Attrition analyses showed only one difference between participating families and families with missing data for main study variables: participating adoptive fathers were younger ($M = 37.97$, $SD = 5.60$) than non-participating adoptive fathers ($M = 40.05$, $SD = 6.17$) at the time of the adopted child's birth, $t(355) = 2.77$, $p = .006$, $d = 0.35$.

Measures

Mathematics achievement. We examined a basic facet of mathematics achievement, *mathematics fluency*, or accuracy and speed on arithmetic problems (e.g., addition, subtraction, multiplication) because mathematics fluency predicts mathematics achievement (Jordan et al., 2003; Mazzocco et al., 2008) and facilitates the acquisition of more complex mathematical thinking (Hartnedy et al., 2005). We assessed mathematics fluency using participants' standardized scores on the mathematics fluency subtest of the Woodcock-Johnson III Achievement Tests (W-J III; Woodcock et al., 2001). This subtest required individuals to solve as many simple addition, subtraction, and multiplication problems as possible in three minutes.

The mathematics fluency measure was administered to children at age 7, to adoptive mothers and fathers when children were 6 and 7 years old, respectively, and to birth parents

when children were 4.5 years old. Because fewer birth fathers participated in the study, we averaged birth mother and birth father scores (when both birth parents' data were available; 30.3% of the sample) to create a composite measure of birth parents' mathematics fluency ($r = .27$, $p \leq .05$, not shown in Table 2). When only one birth parent completed the mathematics fluency measure (birth mother only, 65.1%, birth father only, 4.6%), we used scores from the birth parent with available data.

Covariates. We considered four covariates in relation to the main study variables: obstetric complications, adoption openness, parent education level, and other subscales of the W-J III. We examined obstetric complications (e.g., neonatal complications, prenatal drug use, exposure to toxins) because such risks, along with heritable influences, could contribute to similarities between biological mothers and offspring traits, and potentially lead to overinflated estimates of heritable influences on child outcomes (Marceau et al., 2016). We examined openness in adoption – contact and exchange of information between birth and adoptive parents – because post-adoption contact between adoptive and biological parents could make it difficult to disentangle heritable and environmental influences (for details, see Ge et al., 2008). Parent education level for birth mothers, birth fathers, adoptive mothers, and adoptive fathers was assessed on a scale from 1 to 7, with "1" representing the lowest level of education (less than a high school degree) and "7" representing the highest level of education (graduate program). Finally, we included three other measures of the W-J III (i.e., letter-word identification; reading fluency; word attack), to control for non-mathematics related parent and child cognitive achievement.

Analytic Strategy

We examined correlations between covariates and the main study variables and residualized any covariates with significant associations ($p < .05$) from main study variables, and then used standardized residuals in all subsequent analyses.

A hierarchical regression analysis examined main effects of mathematics fluency scores for (Step 1) birth parents, (Step 2) adoptive fathers, and (Step 3) adoptive mothers on adopted child scores. We then examined whether birth parent scores moderated effects of adoptive father scores, and moderated effects of adoptive mother scores, on child scores (Step 4). Finally, we examined effects of adopted child biological sex on their mathematics fluency scores (Step 5).

Results

Descriptive Statistics

Table 2 displays descriptive statistics and correlations for mathematics fluency scores (both with and without covariates residualized) for the analytic sample. Prior to residualizing covariates, mathematics fluency scores between adoptive mothers and fathers were significantly correlated with one another. Adopted child mathematics fluency scores were not significantly related to birth parent, adoptive mother, and adoptive father scores prior to residualizing covariates. Finally, results indicated no significant correlations between any main study variable and adopted child biological sex.

Heritable and Rearing Environmental Influences on Children's Mathematics Achievement

As depicted in Table 3, the overall regression model was significant. For heritable effects, we found a significant positive association between birth parent and adopted child mathematics fluency scores. For environmental influences, we found a positive association between adoptive father and adopted child scores, but no association between adoptive mother and adopted child scores. Thus, accounting for adoptive fathers scores explained significantly more variance in

adopted offspring mathematics fluency scores than did birth parent scores alone, but the inclusion of adoptive mother scores along with birth parent and adoptive father scores did not account for significantly more variance in adopted child scores compared to the variance explained by including only birth parent and adoptive father scores.

Additional analyses revealed no significant main effect of child biological sex on adopted child mathematics fluency and no interaction between adoptive parent sex and adopted child sex on adopted child fluency scores. Moreover, neither adoptive mother nor adoptive father mathematics fluency scores significantly moderated the association between birth parent and adopted child mathematics fluency scores. We thus trimmed child biological sex and all interaction variables from the final model.

Discussion

The present study used a parent-offspring adoption design to clarify the intergenerational transmission of mathematics achievement at age 7. In line with prior research (see Kovas et al., 2007a), the present findings indicate significant heritable influences on children's mathematics achievement. Additionally, these findings highlight the importance of the rearing environment, or at least aspects of the rearing environment represented by adoptive fathers' mathematics achievement, for children's achievement scores. However, this environmental influence was only evident for adoptive fathers, not mothers. Moreover, we found no evidence to suggest that adoptive parents' achievement moderated associations between birth parent and adopted child mathematics achievement. Finally, child biological sex had no influence on the etiology of children's mathematics achievement.

One clear implication of this work is that both heritable and rearing environmental influences contribute to the familial transfer of mathematics achievement. Heritable

contributions to adopted children's mathematics achievement persisted even after accounting for influences of adoptive mother and father achievement. Similarly, rearing environmental contributions, via adoptive father mathematics achievement, persisted even after accounting for influences of biological parents' and adoptive mothers' achievement. Together, the joint effects of heritability and adoptive fathers' mathematics achievement explained more variance in adopted children's mathematics achievement than did individual influences of either factor. Furthermore, this work went beyond investigating the independent influences of genetic and environmental factors by considering the influence of GxE interactions (i.e., moderation effects) on mathematics achievement, although we found no evidence for such interactions in this study.

We were surprised to find significant associations between mathematics achievement for children and adoptive fathers, but not mothers, given prior research indicating that mothers are children's primary caregivers (Craig, 2006; Nomaguchi et al., 2005) and more recent work suggesting that mothers', but not fathers', engagement in mathematics-related activities at home is associated with mathematics performance in early schooling (del Río et al., 2017). However, very little research in developmental psychology has considered paternal influences on child mathematics achievement. The inclusion of father data was a strength of this study, and these findings highlight the importance of studying mothers *and* fathers in developmental research.

One potential explanation for this finding is that children may receive a higher quantity and quality of support from fathers than from mothers during mathematics-related learning activities. Moreover, children may place more value on math activities with fathers than with mothers, as even young children demonstrate implicit and explicit stereotypes that math is for boys (Cvencek et al., 2011). Hart et al. (2016) found that fathers engaged in more home mathematics activities with children than did mothers, although this parent sex difference did not

affect children's mathematics achievement. Future work should attempt to replicate and extend the present study findings to determine whether paternal influences are consistently stronger than maternal influences for child mathematics outcomes. Additionally, future research should investigate direct observations of mother-child and father-child play during mathematics activities to examine whether parenting behaviors vary by biological sex.

Finally, our findings indicated that child biological sex did not influence heritable and environmental contributions to children's mathematics achievement. This finding is in line with the gender similarities hypothesis (Hyde, 2005), which proposes that boys' and girls' mathematics achievement is more similar than different (Hyde et al., 2008). These findings also replicate results from twin research suggesting no differences in the etiologies of boys' and girls' mathematics achievement (Kovas et al., 2007b).

Despite our best efforts, this study had a number of limitations. First, we used a single measure to assess mathematics achievement, which likely did not capture the full range of children's mathematics competencies in middle childhood. At this developmental stage, children are capable of more than just addition, subtraction, and multiplication, and should also be able to understand number relations (e.g., ordering of numbers; relative size of objects) and numbering (e.g., counting; number estimation). Moreover, research indicates additional, unique heritable influences on child performance in timed versus untimed mathematics measures (Hart et al., 2010), and we did use a timed measure of mathematics in the present investigation. Thus, etiological sources of variance shown in the present study might have differed if we had assessed other measures of mathematics achievement. Future work examining heritable and environmental sources of mathematics achievement should consider including a variety of measures that tap into developmentally appropriate subcomponents of mathematics achievement.

Another limitation is that adoptive families had high educational and economic backgrounds and limited ethnic diversity. However, demographic characteristics of our sample were similar to the other large adoption study in the United States, the Colorado Adoption Project (Plomin & DeFries, 1985), and were representative of birth and adoptive families from participating adoption agencies in the present study (Leve et al., 2019). Nonetheless, in the current study, demographic characteristics of adoptive families (e.g., high economic and educational backgrounds, low ethnic diversity) differed from those of birth families, indicating a potential restriction of range in the environment of adopted children. Despite this difference, recent work indicates insubstantial effects of restriction range on heritable and environmental estimates (McGue et al., 2007). It is consequently unlikely that range restrictions influenced the present study findings.

A final limitation was that we assessed adoptive parents' mathematics achievement rather than specific parenting factors that could be related to child mathematics achievement. As such, the specific environmental mechanism underlying the association between fathers' mathematics achievement and children's mathematics achievement is unknown. Future studies should investigate more specific measures of parenting, including parental supportiveness (Casey et al., 2014). Finally, based on the findings reported here, it is essential that future research examine paternal, and not just maternal, characteristics that may influence mathematics achievement.

This study has a number of strengths due to its design and the sample composition. To the best of our knowledge, this is one of the first studies to test the intergenerational transmission of mathematics achievement using an adoption design. The present findings corroborate evidence from other genetically sensitive studies, namely, twin studies, indicating substantial heritable influences and modest shared environmental influences on mathematics achievement at

age 7. However, our study was unique in its ability to examine contributions of environmental influences from adoptive mothers *and* adoptive fathers by assessing mathematics achievement in both parents. With the inclusion of both adoptive parents, we were able to demonstrate that environmental influences were evident and substantial via adoptive fathers', but not adoptive mothers' achievement scores. Thus, this is the first study, to date, to shed light on the intergenerational transmission of mathematics achievement from the rearing environment provided by mothers and fathers using a genetically sensitive design. This is important because both parents influence heritable and rearing environmental factors. Moreover, within families, parenting behaviors may vary across parents and thus differentially influence child outcomes.

The present study examined intergenerational effects on mathematics achievement at one point in development, when children were seven years old. A remaining question for future research to address is whether these intergenerational transmission pathways are similar at different points in development. Behavioral genetics research suggests that, for mathematics (and cognitive abilities), environmental influences are strongest in early childhood, whereas heritable influences are strongest later in life (e.g., Kovas et al., 2007a). Future research should examine whether adoptive parents' mathematics achievement, and fathers' mathematics achievement, specifically, might be even more influential on children's mathematics knowledge in early childhood.

Genetically sensitive designs offer a powerful way for researchers to ensure that heritable influences do not confound effects of the rearing environment on child outcomes. The present findings demonstrate the utility of using genetically sensitive designs to identify the degree to which environmental factors shape children's developing mathematical competence. These findings also highlight a need for more research to consider effects of fathers when examining

parent-child associations of mathematics achievement. An important implication of this work is that intergenerational transmission processes linking parent and child traits are not one-dimensional. By including various potential sources of intergenerational transmission, we were able to clarify key contributions of heritable *and* environmental processes on mathematics achievement in middle childhood.

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Table 1

Sample Descriptive Statistics

	Birth parents	Adoptive mothers	Adoptive fathers	Adopted children
Age at child birth, *M* (*SD*)	23.75 (5.82)	37.22 (5.20)	37.69 (5.24)	
Age at child placement (days), *M (SD*)				6.67 (12.46)
Race (%)				
Caucasian	69.2	91.4	90.2	57.6
African-American	11.3	3.6	5.0	11.1
Hispanic/Latino	5.6	2.5	1.7	9.4
Multiethnic	6.7	1.1	1.1	20.8
Other	7.1	1.4	2.0	1.1
Median education level	HS degree	4-year college	4-year college	
Median annual household income ($US)	25,001 – 40,000	100,001 –125,000	125,001 –150,000	

Notes. Due to missing birth father data on ethnicity and race variables, birth parents' ethnicity is only representative of birth mothers. Abbreviation: HS = high school.

Table 2

Descriptive Statistics and Correlations for Mathematics Fluency in Linked-Family Triads

Mathematics Fluency		***M* (*SD*)**	**1**	**2**	**3**	**4**
1	Birth parent	91.21 (12.46)	–			
2	Adoptive father	105.99 (12.27)	.07 (.03)	–		
3	Adoptive mother	105.92 (10.04)	.10 (.09)	.16* (.12)	–	
4	Adopted child	101.42 (15.05)	.13 (.18*)	.10 (.16*)	.11 (.11)	–

Notes. Correlations in parentheses display associations between main study variables after residualizing covariates.

**p* < .05.

Table 3

Summary of Hierarchical Regression Analysis for Adopted Child Mathematics Fluency (n = 195)

	b	***SE***	***B***	R^2	***F* Change**
Step 1				.03	6.40*
Birth parent MF	.21*	.08	.18*		
Step 2				.06	4.80*
Birth parent MF	.20*	.08	.17*		
Adoptive father MF	.15*	.07	.15*		
Step 3				.06	1.15
Birth parent MF	.19*	.08	.17*		
Adoptive father MF	.14*	.07	.15*		
Adoptive mother MF	.08	.07	.08		

Notes. $F(3, 191) = 4.16$, $p < .01$, $R^2 = .06$. Abbreviation: MF = Mathematics Fluency.

*$p < .05$.